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Bureaux de Montréal :
Université de Montréal
Pavillon André-Aisenstadt
C.P. 6128, succursale Centre-ville
Montréal (Québec)
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Hubert Verreault[1,*], Catherine Morency[1,2]

[1] Department of Civil, Geological and Mining Engineering, Polytechnique Montréal, P.O. Box 6079, Station Centre-ville, Montréal, Canada H3C 3A7

[2] Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT)

Abstract. In the transportation planning process, most of the model use data collected in a household survey. The needs in modeling and planning are for the AM peak, which basically is for working activity. Increasingly, travel authorities are interested to know and model the people trips in other times of the day. These periods are not only characterized by working activity, but with less recurrent activity like leisure and shopping. Trips related to these activities are less known to other members of the household. In the Montreal household survey, only one person, who knows theoretically the best trips made by the household members, responds for all other. If respondents do not report all trips made by the indirect participant, some key indicators may be biased. This paper aims to demonstrate the existence of proxy respondent bias and to look for trends over time. Data from the past five available surveys of the Montreal Origin-Destination household surveys are used for this study. The paper is organised as follows. First, background elements on proxy respondent bias are presented. The general methodology is then detailed, namely the research objectives, the information system on which relies the trend analysis as well as the description of factors having an incidence on proxy respondent bias evolution. The following sections present and discuss the results of the analysis using typical travel behaviors. The paper then proposes some conclusion and perspectives.

Keywords: Household survey, proxy respondent bias, travel survey methods, self-respondents, decomposition method.

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* Corresponding author: hubert.verreault@polymtl.ca

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INTRODUCTION

Most current transportation planning models use data from household travel surveys. For reducing data collection costs during phone-based surveys, a proxy respondent is often used to gather data on all household members. In addition to reducing costs namely by reducing interview duration, it is believed that interviewing a single respondent can contribute to assure better coherence between household trips and activities. It is normally assumed that respondents know their trips as well as those made by the other household members; this hypothesis can however often be weak. This data collection method has several advantages but also some drawbacks, especially regarding data completeness. For example, we often observe lower trip rates for those whose travels have been declared by a proxy, compared to self-respondents.

Although proxy respondent bias in phone-based household surveys is known, few studies have looked into its evolution over time. In recent surveys, new travel behavior trends have emerged and it is not always clear what are their causes. First, there is a clear understanding that socio-demographic changes affect household structure and that these changes also have an incidence on travel behaviors. Another trend observed in recent years is the general decline in trip rates. These two trends probably have an impact on the scale of respondent bias.

This paper proposes an analysis of the proxy respondent bias related to large-scale household travel surveys conducted in the Greater Montreal Area. Using five consecutive surveys from 1987 to 2008, this research documents respondent bias and models how it is changing over time.

The paper is organised as follows. First, background elements on proxy respondent bias in household travel survey are presented. The general methodology is then detailed, namely the research objectives, the information system on which relies the trend analysis as well as the description of factors having an incidence on proxy respondent bias evolution. The following sections present and discuss the results of the analysis using typical travel behaviors. The paper then proposes some conclusion and perspectives.

BACKGROUND

The study of proxy respondent bias in household surveys is not new. In the literature, two distinct research areas are discussed. The first one is the effect of proxy responding on response rates and survey productivity. The second one is the analysis of the data quality which is obtained using this strategy.

Data quality in household travel surveys seems to be taken for granted. However, most researchers are aware of the limitations. Susan Liss (1) targets proxy bias as areas for potential improvement of data quality in household surveys. However, proxy respondent is widely used in phone-based travel surveys because it reduces operational costs and facilitate data collection among large samples. In addition, the use of a proxy is often recommended as a solution to tackle the issue of survey non-response. (2) This survey method also allows to reach people who might not respond to the survey, such as those out of their home during typical interview hours or children. (3) Non-response in surveys is something that is becoming more and more important. In phone-based surveys, households are usually contacted using the family phone number (fixed line). However, the increase in the number of cell phones makes these types of family landlines more and more obsolete. In Canada in 2013, 60% of households aged 20 to 35 had only cell lines (4).

The use of proxy responding may have impacts of different scales across demographic groups. If the demographic composition of proxy respondent is not uniform then survey results may be biased because the proxy respondent bias is more concentrated is some population segments (5). Several studies address the effect of proxy responses on survey results. Most studies focus on the fact that trip rates are underestimated for the people who did not directly provided their travel information. The FHWA found by studying the NPTS (National Personal Transportation Survey) from 1990 to 1995 that self-respondents

reported 20% more trip and 25% more distance than non-respondents (6). Bose and Giesbrecht (6) also showed, using the NHTS 2001, that the trip rate of self-respondents (4.5) were higher than the one of non-respondents (3.7). In Montreal, Chapleau (8) showed that the trip rate of non-respondent was underrepresented of 0.5 trips in 1998.

Of course, the proxy respondent bias does not apply uniformly to all types of trips. Trips for casual activities such as shopping are more affected than regular trips such as those for work or study. Giesbrecht (9) observed that the difference in trip rates between self and proxy responses are more significant for the non-home-based trips. Badoe and Steuart (10) also showed that the respondent bias in Toronto was significant and it was higher for non-home-based trips. Although the most common findings is the underestimation of trip rate make by indirect participant, other indicators may also be considered as non-mobility and travel distances. (11)

Most studies focus on the identification of travel indicators which are more likely to be affected by proxy responding. However, very few of them are interested in the evolution of this bias over time and across surveys. One could suppose that the bias is decreasing over the years, mainly due to the change in household size and the fact that, as a consequence of this decrease, the proportion of self-respondent will be higher (12). However, other factors may as well influence typical travel indicators and confound with this bias such as a general decrease in trip rates for an average weekday, which is mainly associated with a reduction in the number of leisure and shopping activities conducted during typical weekdays.

For data already collected, it is possible to correct the records in the weighting process by adjusting the non-respondent behaviors to self-respondent's ones (13). This method of course supposes that there is no significant differences between the behaviors of self and non-respondents. Stopher (3) raises the fact that correcting surveys for such bias is a complex task because it can be of different scales depending on the type of trips. He also points out that applying a correction at the aggregate level is simple, but that correcting disaggregated observations is more complex.

Some authors (14) have also questioned the quality of the information provided on the other household members by the respondent. They raise three factors that affect the quality of responses: is the proxy knows information about indirect participants, is the proxy knows the confidence level of expected answers and is the proxy will decide to provide the correct answer to the question? Boehm (15) has also shown that the proxy respondent usually has confidence in his answer; however, they may nevertheless be biased.

GENERAL METHODOLOGY

In this study, a respondent is defined as a person who answers for all household members. A self-respondent is defined as a person who reports directly his trips to the interviewer. An indirect participant is defined as a person whose trips are reported by a proxy.

Data from the Montreal Origin-Destination (OD) household surveys are used for this study. In the Montreal Region, these surveys have been conducted approximately every 5 years since 1970. This study focuses on the data collected over the past five available surveys, from 1987 to 2008. Respondents are reached by phone and only one respondent per household is providing answers to the interviewer. One exception is the 1993 surveys during which the interviewers were allowed to talk to more than one respondent per household and were asked to insist on the conduct of non-home-based trips during the day. This resulted in a higher overall trip rate. At the beginning of the call, the interviewer asks to talk to the person aged 16 years and over whom best knows the trips made by the all the household members. If the respondent does not have a sufficient knowledge of the travel characteristics of all members of the household, an appointment is made to allow gathering the missing information or the interview is considered incomplete depending on the number and type of information missing. These travel surveys have large sample sizes and the overall sampling rate varies between 4% and 5%. The reference population in 2008 was about 3.9 million people and 1.6 million households.

Table 1 presents the key figures regarding the five surveys, including sample size (households and people) and number of self-reporting and proxy-reporting people. It shows that the proportion of self-respondent is increasing since 1987. This can be explained by the decrease in household size, related to the decrease in the number of children per household, population aging as well as an increase in the proportion of people living alone. Respondents are not evenly distributed in the population. Figure 1 presents the proportion of self-respondents by age cohort and gender. It shows that women are more often respondents than men. Also, people aged 16-30 years are the people who are less often respondents for their household. The sampling rate of this age group is also the lowest in the 2008 survey. Hence the proportion of the 16-30 years old who are self-respondents has also decreased over time. This can be explained partly by the fact that some people from these cohorts are probably leaving the family home later in their life, hence having lower probability of being selected as respondent in this type of household. On one hand, if there is a proxy respondent bias for these under-represented groups, the bias will be more important because it will concern a larger sample. On the other hand, if proxy respondent bias is observed for age groups with a high proportion of self-respondents, such as the elderly, then it will have less impact on global indicators since it will affect a lower proportion of the sample.

Table 1 : Samples for the Montreal OD survey since 1987

Survey	Household sample	Person sample	Self-reporting	Proxy-reporting	% Self-reporting
1987	53 177	137 365	53 177	84 188	38.7%
1993	61 988	160 514	61 988	98 526	38.6%
1998	65 227	164 075	65 227	98 848	39.8%
2003	58 000	139 527	58 000	81 527	41.6%
2008	66 124	156 720	66 124	90 596	42.2%

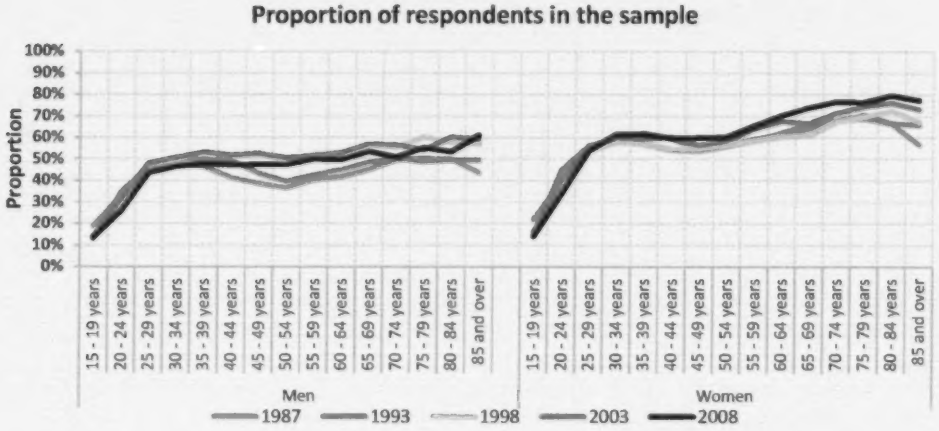

Figure 1 : Proportion of self-respondents in the sample, by age cohort and gender, from 1987 to 2008

Subsequent analyzes were performed using two samples, self-respondent and indirect participant. For the 1998 to 2008 surveys, it is possible to directly identify who the respondent is for the household since there is a data field containing the information. However, this information is not directly coded for the 1987 and 1993 surveys. For these surveys, it was assumed that the respondent is the first household member in the file. This is based on the fact that, in 2008, 99.85% of proxy respondents were the first person of the household to be surveyed.

This study compares indicators for the two samples mentioned above, self-respondents and indirect participants. However, the composition of these samples may also have an impact on the bias. Age and gender have been used as control variables. Other socio-demographic variables may also be significant. Figure 2 shows the proportion of self-respondents and indirect participants who are full-time workers. Indirect participants have a slightly larger proportion of full-time worker for men and women workers. This can be explained by the fact that part-time workers often have atypical schedules overlapping operating hours of the survey.

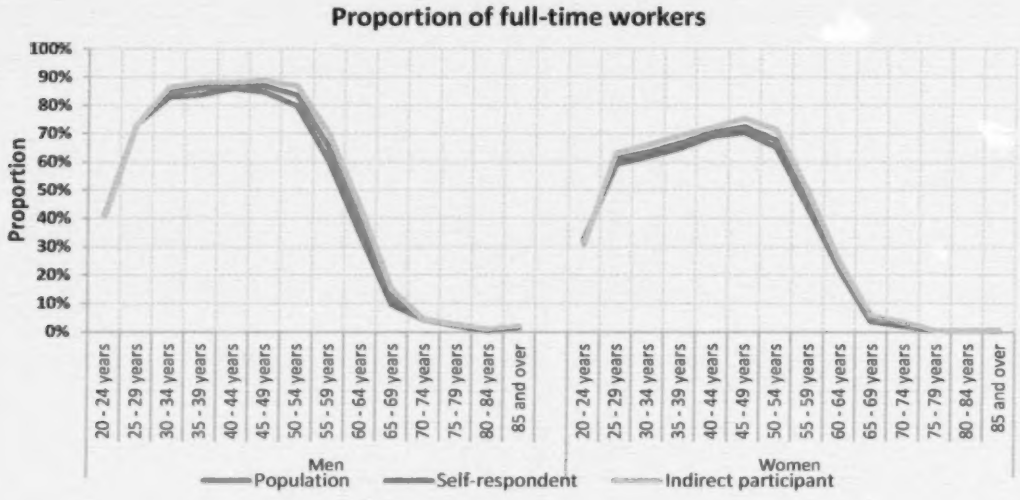

Figure 2 : Proportion of people aged 15 and over who are full-time worker for the population, the self-respondents and the indirect participants (OD 2008)

Figure 3 shows the proportion of self-respondents and indirect participants who are living in a household with at least one car. The difference between self-respondents and the other survey participants is explained by the distribution of household types. Indeed, household size is correlated with its car ownership. Difference among elderly women is explained by the high proportion of people living alone and the low proportion of people having a driving license in this subgroup.

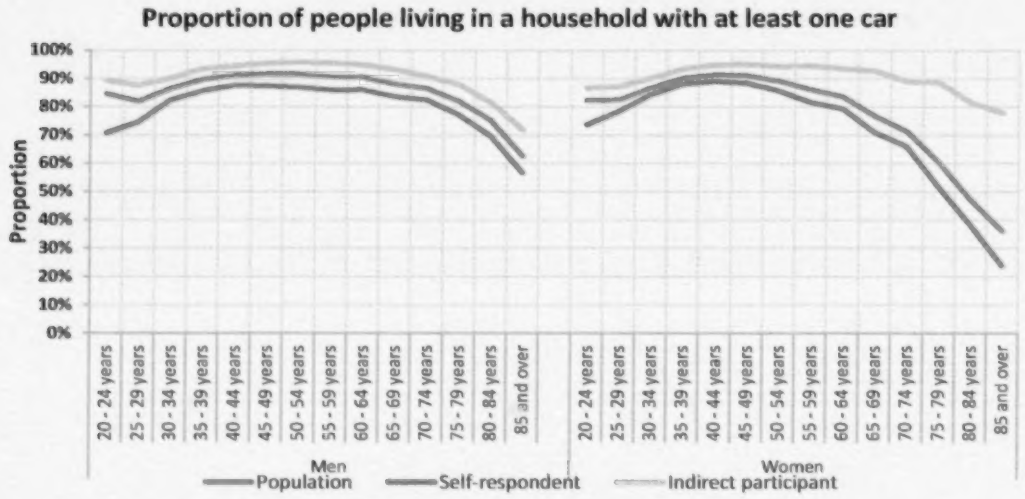

Figure 3 : Proportion of people aged 15 and over living in a household with at least one car for the population, the self-respondents and the indirect participants (OD 2008)

INFLUENCING FACTORS

The study on proxy respondent bias focuses mainly on trip rates. Two main factors can therefore directly influence the impact of this bias. The first factor is the decline in household size, observed since 1987. The number of person per household rose from 2.56 in 1987 to 2.38 in 2008. This reduction causes an increase in the number of self-respondents and should, thereby, lead down proxy bias.

The second factor is based on the probability that the proxy respondent do not declare a trip. A high number of trips made by one person increase the probability of non-reporting one of these trips. Of course, the probability of not declaring a trip depends on the trip rate and the trip purpose. Since 1993, we observe a decrease of the trip rates per person in Montreal. If this decline is due to a change of trip behavior, it should lead to a decline of proxy respondent bias. To confirm that the decrease is related to the trip behavior and not to change of proxy respondent bias, Figure 4 and Figure 5 show the evolution of trip rate since 1987 for self-respondents only.

It is assumed that other bias, such as under-reporting bias of trips, are constant for all OD survey. The findings follow:

- Figure 4 shows a decrease of trip rates for the entire population since 1993;
- Figure 5 shows, since 1993, a decrease of working trips per person for men but a slight increase for women. This increase is mainly due to the massive entry of women into the labor market.

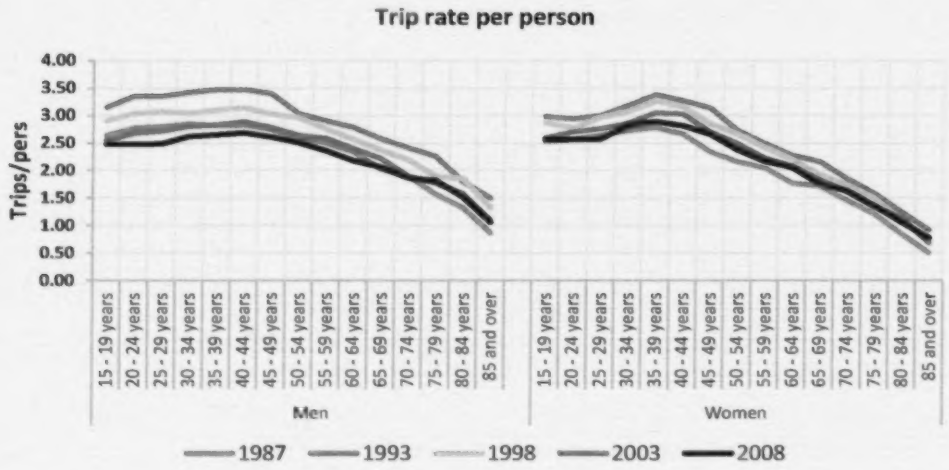

Figure 4 : Number of trips per person from 1987 to 2008 for self-respondents to the OD survey

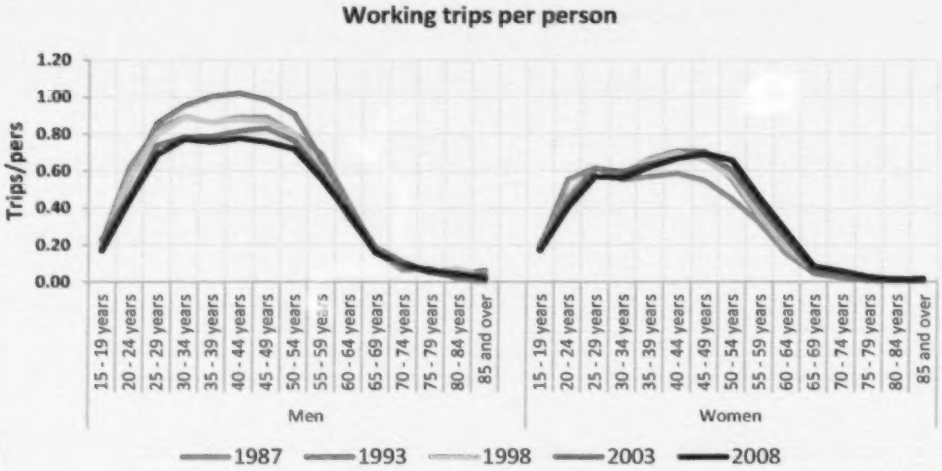

Figure 5 : Number of working trips per person from 1987 to 2008 for self-respondents to the OD survey

Declining trip rates since 1993 seem to apply to the entire population, except in a few specific cases. As discussed above, a decrease in the number of trips should lead to a decline in proxy bias.

EVOLUTION OF PROXY RESPONDENT BIAS

This section compares some trips indicators between the self-respondent and indirect participant samples. The objective is to determine whether the two samples have different trip indicators. If there is a difference between the two samples, it can either be the result of the proxy bias or a real difference in travel behaviors. For the following analysis, we suppose that this difference is solely the result of the proxy-respondent bias. A t-Student test, at a confidence level of 95%, is used to determine if the differences observed between the two samples are significant. The differences between the two samples are also analyzed between surveys to determine if the bias is increasing or decreasing. Estimates are segmented according to cohort and gender.

Figure 6 shows the overall trip rate per day for the Great Montreal Area GMA. The trip rate of self-respondents is higher than for the indirect participants for all cohorts. In 2008, the average difference was 0.50 trips per person. The differences between the two samples by gender and cohort are significant at a confidence level of 95%. Proxy respondent bias for this indicator is decreasing since 1993, and this decrease is more pronounced for men.

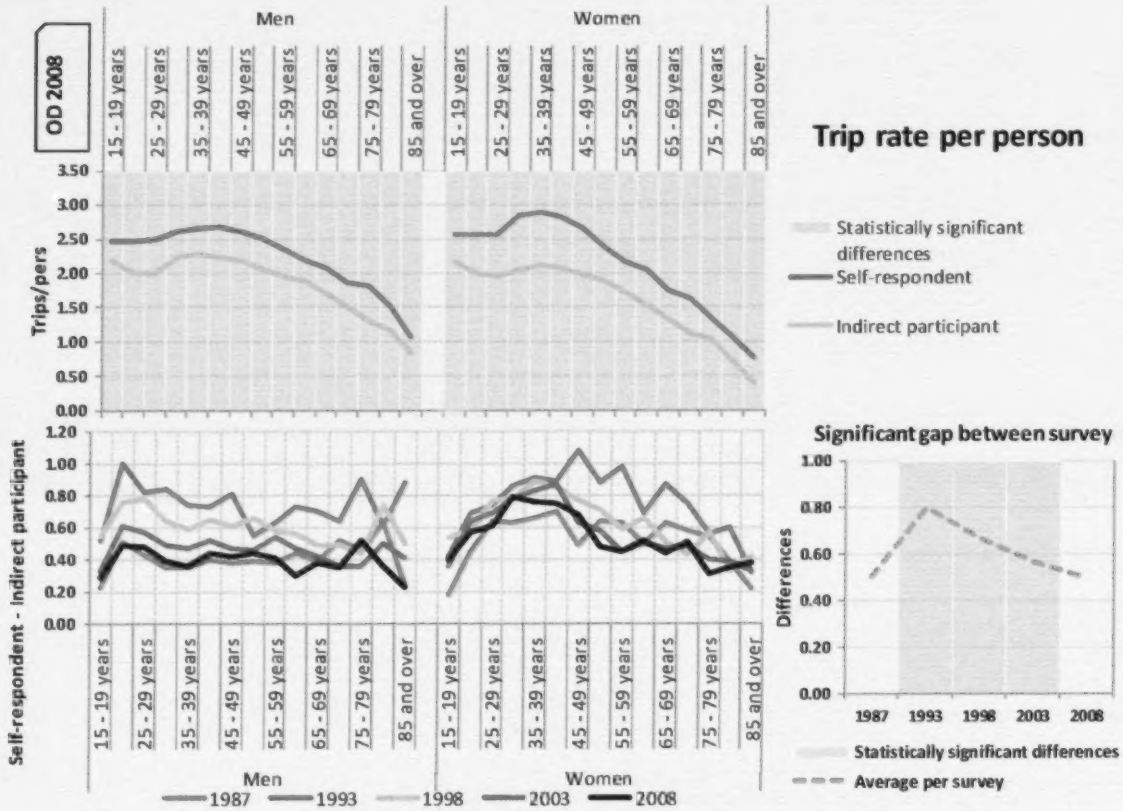

Figure 6 : Comparison of overall trip rates between the self-respondents and the indirect participants (Montreal Area)

Figure 7 shows similar results for the proportion of non-mobile in the population. Indirect participants have a higher proportion of non-mobile than self-respondents. This difference between the two samples is fairly constant for all cohorts and is statistically significant for almost all groups. The proxy bias has a direct effect on other indicators based on trip rates. The bias decreased between 1987 and 1998. Since 1998, it seems to be constant.

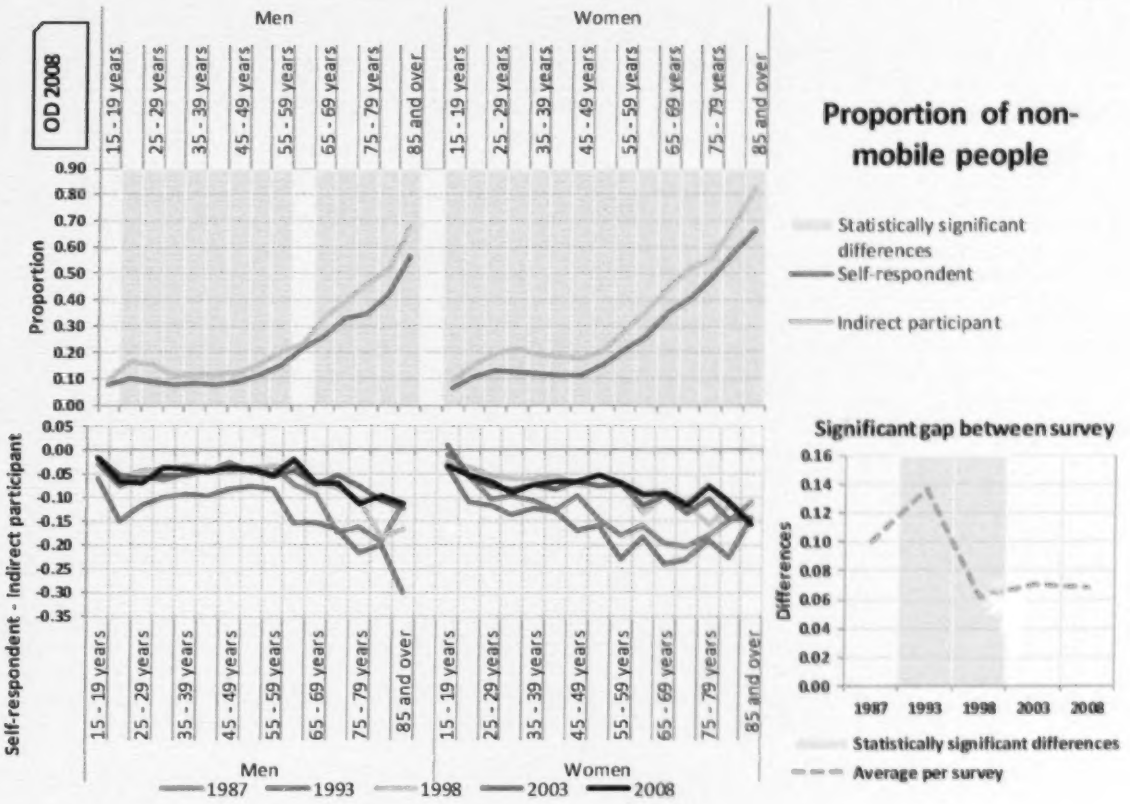

Figure 7 : Comparison of non-mobile proportion between the self-respondents and the indirect participants (Great Montreal Area)

Figure 8 shows the results for frequency of non-home-based trips per person per day. The trip rates are higher for self-respondents than for indirect participants. The difference between the two samples is also higher among women. The differences are significant for almost all cohorts and the average difference is 0.14 trips per person. This represents 29% of the gap observed for the total number of trips per person. The bias is declining since 1993.

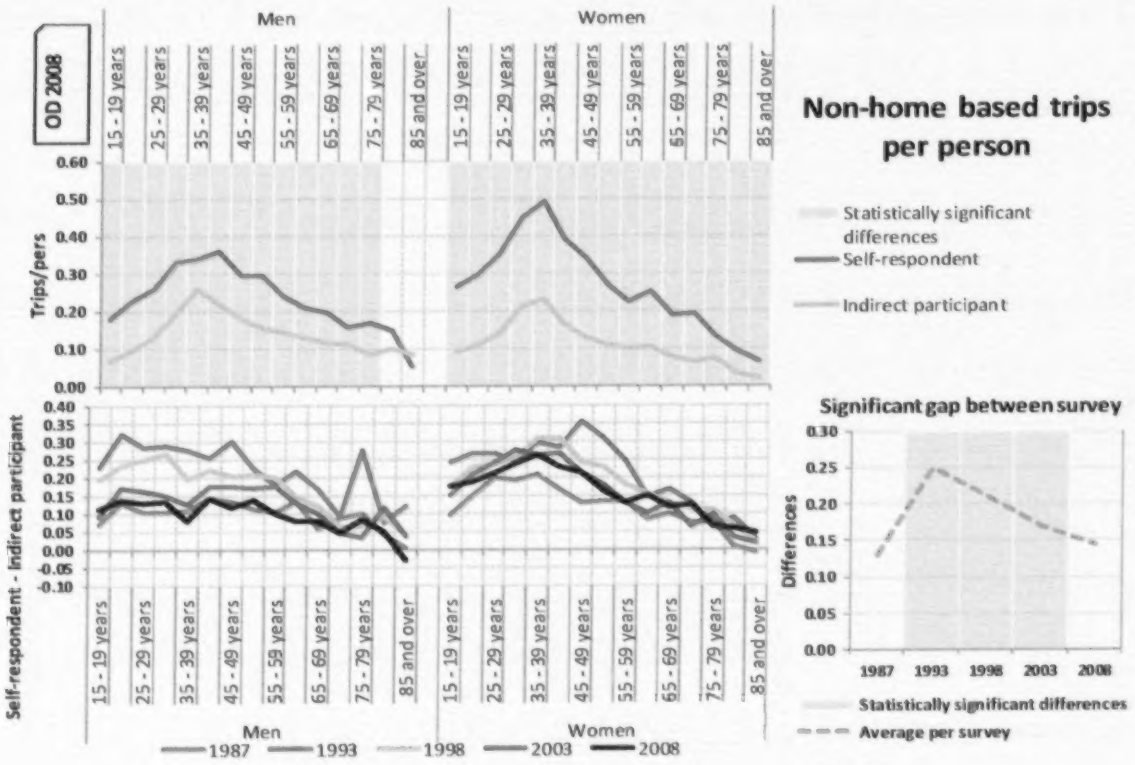

Figure 8 : Comparison of non-home based trips per person per day between the self-respondent and the indirect participants (Great Montreal Area)

Figure 9 shows the results for the proportion of the population who made at least one trip driving someone or picking someone per day. There are differences between the results for men and women. Differences appear quite non-existent for men while they are important for women. The overall average for men (22.0%) and women (21.9%) are almost equal. Women seem to make more trips of this type, mainly due to family carpooling, than men. The differences between the two samples appear to be slightly lower for men and quite stable for women since 1987.

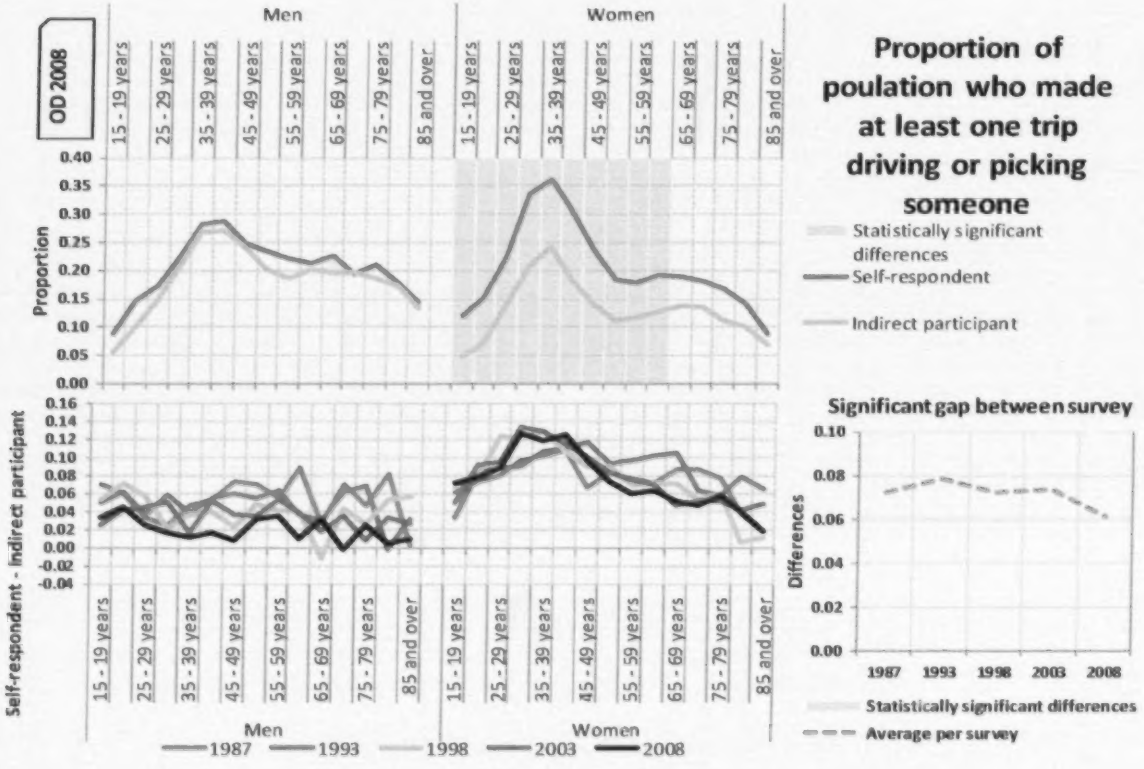

Figure 9 : Comparison of proportion of population who made at least one trip driving or picking someone between the self-respondent and the indirect participants (Great Montreal Area)

Figure 10 shows the total distance traveled per person per day (only people doing at least one trip are included). Unlike what has been observed so far, very few differences are observed between the two samples. The distance traveled by a self-respondent and indirect participants are very close, confirming the fact that the non-declared trips of the indirect participants are short-distance trips or intermediate stops in the trip chain that cause little extra distance. Moreover, this trend appears to be stable since 1987. Following these observations, it is possible to use indicators based on trip chains instead of trips to limit the impact of proxy respondent bias.

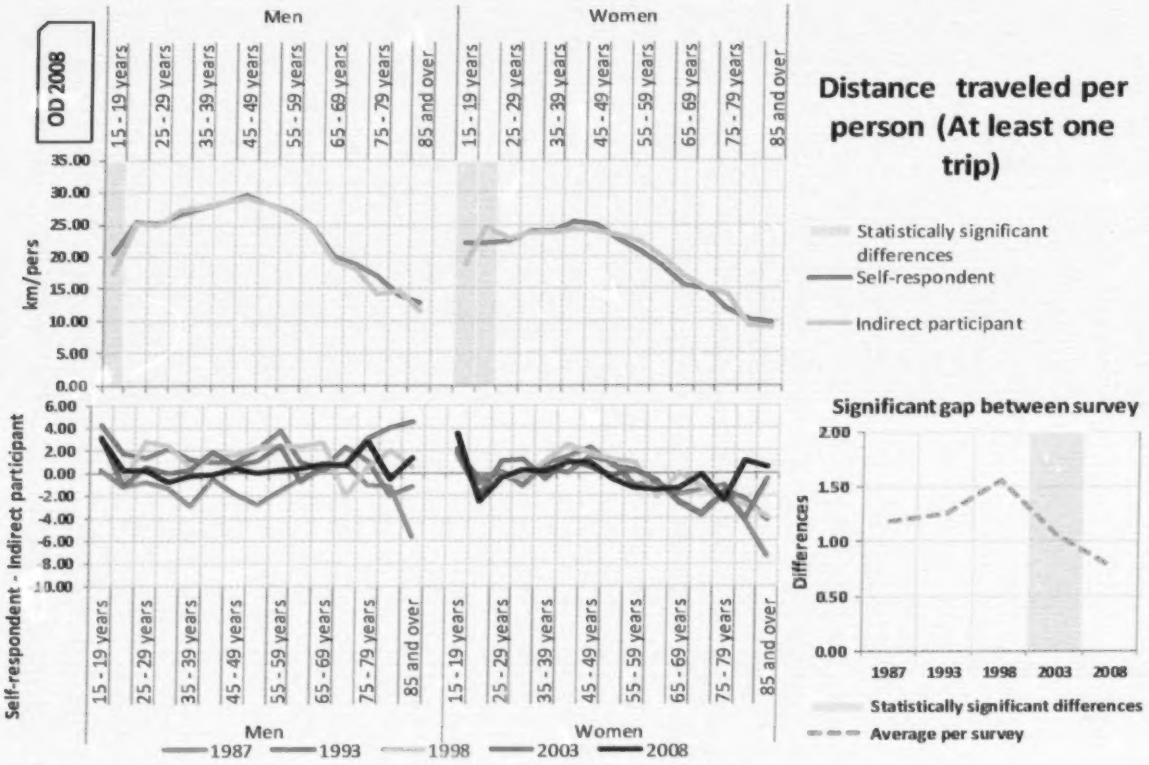

Figure 10 : Comparison of total distance per person per day between the self-respondent and the indirect participants (Great Montreal Area)

Oaxaca-Blinder decomposition

Gender and cohort were used as control variables in the previous analysis. However, other variables related to the composition of the population may have an influence on the results. For example, a sample that would include more full-time workers would imply differences in trip behavior that is related to the composition of the sample and not to the presence of proxy. To better understand the differences observed in the previous graphs, the Oaxaca-Blinder decomposition method (16) was used. This decomposition method allows to separate the effect, when comparing two samples, which is related to the composition of the sample and the structure effect. Stata module (17) was used to estimate the model for various indicators, including those discussed previously.

The main objective of this method is to decompose differences in mean across two groups for an indicator. It is assumed that the indicator setting model is linear. In this study, the groups are the self-respondents(S-R) and the indirect participants (I-D) and each is represented by a linear equation.

$$Y_{S\text{-}R} = \beta_{S\text{-}R} * x_{s_R} + const_{S\text{-}R}$$

$$Y_{I\text{-}P} = \beta_{I\text{-}P} * x_{I\text{-}P} + const_{I\text{-}P}$$

Equation 1 : Linear equation for each group

The composition effect is computed as the difference between the self-respondent and the indirect participant means multiplied by the indirect participant coefficients ($\Delta x * \beta_{I\text{-}P}$). The corresponding structure effect is computed as the difference between the self-respondent and the indirect participant coefficients ($\Delta * \beta x_{S\text{-}R}$). The interaction is the unexplained effect. The results are presented in Table 2.

The explanatory variables in the linear model are as follows:

- Cohort
- Gender
- Home location
- Number of people in the household
- Presence of a car in the household

Table 2 : Result of Oaxaca-Blinder decomposition method

			Significant	Composition	Coefficient	Interaction	Composition	Coefficient	Interaction
		Difference		% of difference explained			Statiscally significant		
All people	Trips per person	-0.37	***	-60.2%	150.2%	10.1%	***	***	***
	% non-mobile	0.01	***	-437.4%	587.0%	-49.6%	***	***	***
People who made at least one trip	Trips per person	-0.42	***	-11.6%	101.9%	9.7%	***	***	***
	Working trips per person	0.02	***	122.6%	-2.4%	-20.3%	***		
	School trips per person	0.12	***	78.2%	21.4%	0.4%	***	***	
	Leisure trips per person	-0.10	***	29.2%	87.0%	-16.3%	***	***	***
	Shopping trips per person	-0.18	***	45.7%	62.2%	-7.9%	***	***	***
	Other trips per person	-0.14	***	-13.7%	79.0%	34.7%	***	***	***
	Car-driver trips per person	-0.37	***	-24.9%	125.2%	-0.3%	***	***	
	Car-passenger trips per person	0.08	***	-7.7%	179.4%	-71.6%	**	***	***
	Public transit trips	-0.02	***	-108.5%	-25.7%	234.2%	***		***
	Walking trips	-0.15	***	47.4%	71.7%	-19.1%	***	***	***
	Am peak trips per person	0.05	***	174.0%	-11.7%	-62.3%	***		***
	Non-home-based trips per person	-0.17	***	-1.7%	97.6%	4.1%		***	*
	Distance per person trips per persor	0.82	***	97.1%	20.5%	-17.6%	***	**	**
	Activity duration per person (min)	132.60	***	48.6%	43.2%	8.1%	***	***	***

Confidence interval :*** 99%, ** 95%, * 90%

All indicators studied in Table 2 show a significant difference between self-respondents and indirect participants, when other variables are controlled for. Some conclusions can be drawn:

- The composition of the sample contributes significantly to the gap for almost all indicators. This confirms that the use of control variables such as age and gender is necessary when the two samples are compared.
- The coefficient component contributes significantly to the gap for all variables except for the working trip per person, public transit trip per person and AM peak trip per person. These findings are explained by the fact that these types of trips are often linked together and correspond to constrained trips which are less likely to be omitted by proxy respondents.

CONCLUSION AND PERSPECTIVES

It has been shown in this paper that the proxy respondent bias is decreasing. This decrease is partly caused by lower household size and lower trip rates since 1993. However, we can ask whether this trend will continue in the coming years. On the one hand, household size will likely continue to decline due to population aging. On the other hand, it is difficult to predict whether trip rates will continue to decrease for all cohorts. In addition, we must ensure that other bias do not affect the results. Forecasting models used in Montreal does not directly consider the change regarding the scale of proxy respondent bias.

Several efforts are already made to limit the respondent bias during data collection. However, a focus on indirect participants who are declared non-mobile would potentially improve results. It would also be possible to call back households when information is missing or incomplete for indirect participants. Another option would be conduct people-based instead of household-based surveys. However, this would increase the cost, increase difficulty of reaching a representative sample (some people being less likely to participate) or reduce sample size sample. However, for some analyzes, it may be better to focus on a self-respondent sample only.

Perspectives

Another interesting aspect of proxy bias would be to compare if the bias has the same impact according to the survey mode. With the increase of non-response, it is difficult to obtain a representative sample from one survey mode. In this perspective, several organizations are currently testing complementary data collection methods such as postal or web questionnaires. In this case, it will be important to assess the proxy bias for each survey mode before performing data fusion. Srinivasan and Yennamani (17) have shown that proxy bias was one of the causes of differences between two samples from two different survey modes.

In addition, it will be important to find mechanisms to correct the proxy respondent bias in Montreal. The impact of these non-reported trips is not negligible. Assuming that non-respondents have the same trip rate, by cohort and gender, as self-respondents, it is estimated in 2008 that 10% additional trips would be made in the Montreal area; this amounts to about 750,000 trips over a total of 7 million trips.

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